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WORLD WATER CRISIS LOOMS

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SUMMARY: An investigation was undertaken to develop a robust solar water purification system for remote areas that have neither suitable potable water nor energy supplies. A study of the challenges of global water supply and existing treatment methods was made to aid the development of the design. Current world water resources are examined regarding climate change, population growth and irrigation and the likely effects are assessed for human health and mortality, potential for conflict, economics and effect on ecosystems. Solutions are posed in the form of development goals, wastewater reuse and desalination. Objectives for the design of effective desalination systems are given. Predictions are also made for various scenarios of response to the looming crisis. The most disturbing is that if there is no response, five billion people are predicted to die rapidly from 2040 on. Action is required now, a global crisis is already happening, and, if not dealt with, water pollution may dramatically decrease the global population in the 21st century with people in less developed regions paying the heaviest prices.

1. WORLD WATER RESOURCES

The absolute dependence of all life on the availability of water is becoming more apparent as environmental pressure mounts. Only 2.5 percent of the Earth's total water supply is fresh water, and around 70% of that is in the polar ice caps, or at inaccessible depths below the earth's surface. Only about 0.007% is easily accessible (Al-Gobaisi, 2000). Nevertheless, there are 4.3 million cubic kilometres of fresh water in the ecosystem of varying distribution and quality. Currently 160 km³ is used each year without replenishment (Bindra, 2001). Environmental advocates have repeatedly warned that the Earth's water resources are finite. The predictions that once seemed so unlikely are beginning to come true: the finiteness is looming.

Water is deemed to be scarce when supply for personal use is less than 1,000 m³ per person per year (Al-Gobaisi, 2000). UNESCO has compiled an extensive list of water use around the globe, including the following list of the ten most water stressed countries or regions in the world (see Table 1). Twenty-six countries with a total population of 232 million people already face water scarcity. The Middle East is the most concentrated region; there are predictions that water - not oil - will be at the centre of any future Middle East wars (Gleick, 1992).

UNESCO Director-General Koïchiro Matsuura says the average supply of water worldwide per person is expected to drop by a third over the next 20 years. The UN estimates that if present water consumption trends continue, in less than 25 years, 5 billion people will be living in areas where it will be virtually impossible or difficult to meet the very basic water needs for sanitation, cooking and drinking (World Water Facts, 2002). Water resources will steadily decline because of expected climate change, pollution and population growth.

Table 1: Annual per capita water supply for the world's ten most water stressed countries/regions (UNESCO, 2003)

| Country/Region | Annual per capita water supply (m ³ /p.yr) |
|------------------------|---|
| Kuwait | 10 |
| Gaza Strip | 52 |
| United Arab Emirates | 58 |
| Bahamas | 66 |
| Qatar | 94 |
| Maldives | 103 |
| Libyan Arab Jamahiriya | 113 |
| Saudi Arabia | 118 |
| Malta | 129 |
| Singapore | 149 |

1.1 Expected Climatic Change

Climate change is expected to make up an estimated 20% of the increase in global water scarcity as global temperatures rise (UNESCO, 2003). Humid areas can expect more rain, while many drought-prone regions and even some tropical and sub-tropical regions will face smaller and more erratic rainfall (Warrick, 2002). Floods already affected more than 75% of all people hit by natural disasters in the 1990s (UNDESA, 2002). A report into the current droughts in eastern Australia says that while high temperatures and low rainfall are equal with the worst droughts so far, evaporation rates for reservoirs, rivers, vegetation and soil are the highest ever recorded (Anon b, 2003). Water quality in natural systems is predicted to worsen with rising pollution levels and water temperatures.

1.2 Pollution

About 2 million tonnes of waste are dumped into rivers, lakes and streams every day. The volume of polluted water worldwide is estimated at 12,000 km³, more than the total of the world's ten largest river basins (UNESCO, 2003). The major source is human sewage. For example, out of some 3,119 towns and cities in India, only 217 have partial or complete sewage treatment facilities. Of 78 rivers monitored in China, 54 are categorised as "seriously polluted" with untreated sewage and industrial wastes (Sivakumar, 1997). Asian rivers are the most polluted at three times the global average for faecal coliforms, and 20 times more lead than those of industrialized countries. Therefore, if pollution just keeps pace with population growth, the world will effectively lose 18,000 km³ of freshwater by 2050 – almost nine times the total amount countries currently use each year for irrigation (UNESCO, 2003).

2. WORLD WATER DEMAND

2.1 Population Growth

While the world's demand for water from 1900 to 1995 increased sixfold, this was more than twice the rate of population growth (World Water Facts, 2002), indicating that increasing individual usage rather than increasing population has the greatest impact. World population should still reach about 9.3 billion by 2050 compared to 6.1 billion in 2001 despite declining

birth rates. This is a 52% increase in 49 years. The impact is not evenly spread: South America has 26% of the world's freshwater and only 6% of its people while Australia and Oceania have 5% water and less than 1% people respectively. Of great concern is the inability of Asia to support 60% of the global population with only 36% of its water (refer Figure 1).

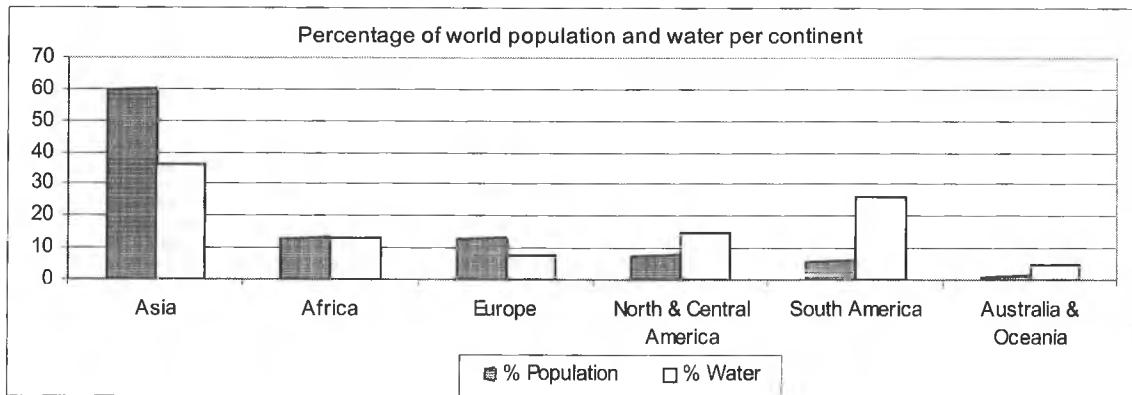


Figure 1: The percentage of the world's population and water supply found in each continent (adapted from UNESCO, 2003)

The trend toward increasing urbanisation is further concentrating demand on limited resources, and creating waste disposal problems. By 2025 the number of the world's people living in cities is expected to increase by 1.7 billion (Bremere et al, 2001). If these trends continue as expected, Asian mega cities without adequate treated water supply and sewerage pose the future's most lethal environment for humanity.

2.2 Irrigation

Irrigation currently makes up 70% of the world's water withdrawals (Pearce, 2002). Twenty of 170 countries and territories surveyed already irrigate with more than 40% of their renewable water resources. Another 16 countries use more than 20%. By 2030 South Asia will use an average of 40% of water resources for irrigation, and the Near East and North Africa will be above 58%. In contrast, sub-Saharan Africa, Latin America and East Asia will remain far below the levels required, despite providing most of the predicted agricultural expansion in the next 30 years (UNESCO, 2003). Figure 2 compares how water is used in developed and developing nations with the world average. The developing world relies on water in agriculture for survival while the rich world uses water to create wealth through industry.

Currently an estimated 815 million people are undernourished and around 25,000 die from hunger every day. The UN Millennium Goals (2000) pledged to halve that number by 2015. This will require another 45 million hectares of irrigation by 2030 in 93 developing countries, where most population growth is expected to take place. While this potential expansion has the land available, it will require a further 14% increase in water for irrigation. Improving efficiency of land and water use is the challenge. Irrigation currently wastes close to 60% of the water used through leakage and evaporation, and this rate is not expected to improve much. Waterlogging and salinization through poor drainage and irrigation practices have damaged around 10% of global irrigated pastures.

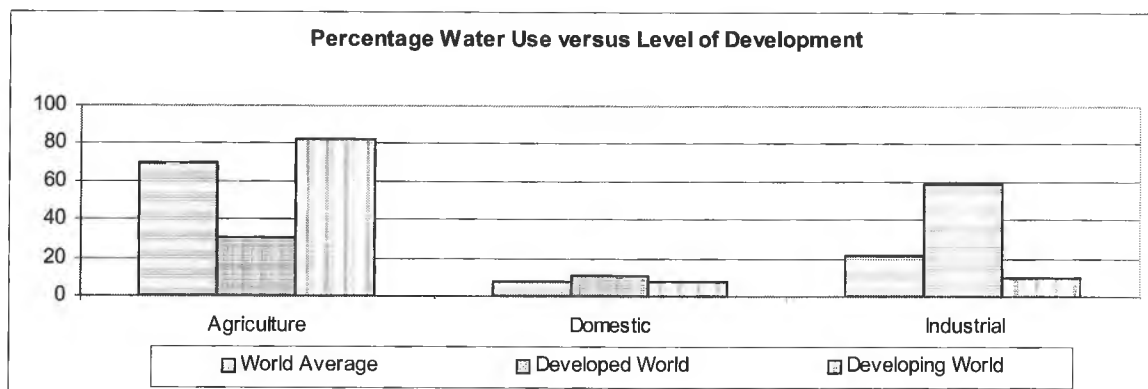


Figure 2: The percentage of water allocated to major uses in the developed and developing world against the world average.

3. OUTCOMES

3.1 Human Impacts

According to the UN and the World Health Organization, 80% of diseases in developing nations stem from consumption of and exposure to unsafe water. These kill more than 24,000 people each day, including 6,000 children under 5 years old (www.thehungersite.com). Over 2.2 million people die annually from diseases linked to contaminated drinking water and poor sanitation. Water vector-borne diseases also add up: about a million people die from malaria each year and over 200 million suffer from schistosomiasis, problems the developed world solved decades ago.

3.2 Water Wars or Peace

There are 145 nations bordering the 261 international river basins. More than two countries share about one-third of these rivers, and 19 involve five or more. Large parts of Africa and the Middle East share over half their water supplies, as does southern Latin America.

A study of all 1,831 water-related interactions between two or more countries over the past 50 years showed that the majority (1,228) were co-operative, showing that water provides potential for peace. They include 200 water-sharing treaties or new dams constructed. There were 507 conflicts, only 37 of which involved violence. The military acted in 21 of these; 18 of them involved Israel and its neighbours (UNESCO, 2003). Israel has reduced water access in the occupied West Bank and Gaza Strip to one-fiftieth of international standards (Bindra, 2001). Consider also that it has to share the Jordan River with Syria, Lebanon, Jordan and Palestine and the potential for war is clear. Kofi Annan, the UN Secretary General, had called for water agreements to limit conflict before the Johannesburg conference, but it was stifled at the apparent insistence of Turkey. Turkey is currently damming the headwaters of the Tigris and Euphrates Rivers, angering downstream Iraq and Syria (Pearce, 2002).

While international rivers are highly visible, groundwater supplies (aquifers) are largely ignored. This is despite the massive volumes of generally high-quality water involved (estimated at 23,400,000 km³ compared with the 42,800 km³ in rivers). Aquifers store up to 98% of accessible water supplies. Annual extractions of between 600 to 700 km³ provide around 50% of global drinking supplies, 40% of industrial demands and 20% of irrigated agriculture (UNESCO,

2003). Since many governments are not even aware that they share aquifers with other countries, this does represent a potential new area for conflict. In May 2003, Brazil, Argentina, Uruguay, and Paraguay launched a project for the preservation of the 1.2 million km³, 37 trillion-litre Guarani Aquifer (Water Observatory, 2003). In June 2003, eight major environmental organisations asked the Evian meeting of G8 world leaders to recognise transboundary rivers, lakes and aquifer management as a priority, and to allocate \$1 billion over 10 years to finance strategic cooperation (WWC, 2003). Investment of this type will lead to peaceful co-existence, clearly the more sustainable approach.

3.3 Economic Status

Safe water availability is generally linked to economic status. Over the last 20 years water quality has improved in most industrialised countries, due mainly to increased sewage treatment. The largest threats to water safety in the developed world are from industrial and chemical pollution, especially agricultural run-off. England has 41,500km of rivers, however only 2,700km have good quality water suitable for potable abstractions (Walker, 1992). Unpolluted groundwater is the best source, however currently more than half the population of OECD countries and more than 70 percent of the population of the USA drinks water that has passed through wastewater treatment plants (OECD, 1993). The danger of treated wastewater is that not all the impurities may be removed. Additionally the chemical agents used in treatment may themselves pose health risks.

In developing countries, especially around urban areas, water quality is generally deteriorating. Approximately half the population in the Third World is still without safe drinking water (Pearce, 2002). The greatest difficulties in providing safe water are the cost of piping water to more people, and the logistical problems of protecting water supplies from sewage pollution. Poor people with the most limited access to safe water supplies have to pay significantly more for it. For example in Delhi, India, the poor are charged US\$4.89 per m³, while families with piped connections pay just US\$0.01. Vendors in Vientiane, Lao People's Democratic Republic, charge \$US14.68 per m³, compared to municipal tariffs of US\$0.11/m³ (UNESCO, 2003). Governments and community organisations need to co-operate to actively remove such disparities.

3.4 Ecosystems

Many ecosystems are already under severe stress and global climate changes are predicted to increase it. "By the year 2025, it is predicted that water withdrawal will increase by 50% in developing countries and 18% in developed countries," states UNESCO. "Effects on the world's ecosystems have the potential to dramatically worsen the present situation". The long list of places destroyed or at grave risk from increased water extraction includes the Florida Everglades and Mono Lake in the USA, China's Yellow River, the Donana wetlands in Spain, Sudan's Sudd swamps, Botswana's Okavango Basin, Lake Chad in the Sahara and the Aral Sea in the former USSR (Sivakumar, 1997). The Aral Sea became a salt-encrusted wilderness after engineers diverted two major rivers for human use. New major diversion schemes are planned for China, India, Spain and the Central African Republic (Pearce, 2003).

Areas that receive run-off are threatened too. Wildlife in the Kesterton wetland of California was devastated when selenium from irrigation water passed safe levels. Only the die-off alerted authorities to the problem (Qashu, 1995). The loss of bio-diversity is also alarming. In inland waters, 24% of mammals and 12% of birds are threatened. Between 34 and 80 fish species have become extinct since the late 19th century, six since 1970. Only ten percent of the world's fish species have been studied in detail: one-third of these are at risk (UNESCO, 2003).

4. SOLUTIONS

4.1 Development Goals

The UN Millennium Development Goals (2000), International Freshwater Conference at Bonn (2001), the World Summit on Sustainable Development (Johannesburg, 2002) and the 3rd World Water Forum (Kyoto, Osaka and Shiga, 2003) committed to halve the number of people without safe drinking water and basic sanitation by 2015. This means providing services for 1.5 billion people (100 million each year or 274,000/day) from 2000 to 2015. Since inadequate sanitation only leads to water pollution, another 1.9 billion people require basic sewage services (125 million each year or 342,000/day). This is triple the current rate of connection (Pearce, 2002). It is estimated that the first interventions would cost about US\$12.6 billion (UNESCO, 2003) with an annual figure of \$20 billion, double the \$10 billion currently spent (UNDESA, 2002).

However, countries have not fulfilled any promises made at the 1992 Rio Earth Summit, and there are no binding targets or powerful body to oversee these new commitments. Some progress was made, with the percentage of people with improved water supply increasing from 79% (4.1 billion) in 1990 to 82% (4.9 billion) in 2000. Access to sewage facilities increased from 55% (2.9 billion) to 60% (3.6 billion). This still left 1.1 billion without improved water supply and 2.4 billion without improved sanitation (SOPAC, 2002). Again Asia has a disproportionate share of need (refer to Table 2).

In November 2002, the United Nations Committee on Economic, Social and Cultural Rights affirmed that access to adequate clean water for personal and domestic use is a fundamental human right. However it is not legally binding on the 146 International Covenant States; it is referred to as “soft law”. The Universal Declaration of Human Rights does not include water; it was considered so fundamental that its explicit inclusion was thought unnecessary. Water is actually mentioned only in the Convention on the Rights of the Child, as an element of the right to the highest attainable standard of health. The 1986 Declaration on the Right to Development states that the persistent conditions of underdevelopment in which millions of humans are “denied access to such essentials as food, water, clothing, housing and medicine in adequate measure” represent a flagrant “mass violation of human rights” (UN, 2003).

The problems are well documented, the solutions are apparent, the expertise is present, the threat is real, yet “inertia at government level, and a world population not fully aware of the scale of the problem means we fail to take the needed timely corrective actions and put the concepts to work” (UNESCO, 2003).

4.2 Treated Wastewater

Using treated wastewater could ease the water crisis in two ways by. Firstly re-use would stop pollution of freshwater resources. One litre of sewage pollutes nine litres of freshwater, so the volume to dilute the estimated 1,402 km³ of wastewater disposed of in 1995 was over 6 times the total world water use (IHP, 2000, Simonovic, 2002).

Table 2: Percentage of continental populations without access to improved water supply and basic sanitation (adapted from UNESCO, 2003)

| Continent | Percentage without Improved Water Supply | Percentage without |
|---------------------------|--|--------------------|
| Asia | 65 | 36 |
| Africa | 27 | 13 |
| Europe | 2 | 8 |
| Latin America & Caribbean | 8 | 15 |

Water pollution is the most important future issue on the global scale so re-use will save vast amounts of dilution water and pollution, leaving more and higher quality water for ecosystems and potable uses. Secondly wastewater can also provide for irrigation, lessening freshwater abstraction. This resource is already used for about 10% of irrigated land in developing countries and there is scope for more. It can actually improve soil fertility with proper treatment (UNESCO, 2003). There is also potential for industrial reuse and aquifer recharge.

4.3 Desalination

Better management of water resources and the environment can limit pollution, but cannot provide immediate answers to the problems that exist now. There is a range of treatment options available but they have limited use because of limited effectiveness against some types of pollutants, energy required to run them and their cost of implementation. Reliable, cost-effective methods are needed to supply safe, potable water to society in many areas in ways that won't further degrade the environment. Ecologically sustainable development through renewable sources is the goal.

Desalination by distillation and membrane processes are key treatment methods that meets these requirements. Distillation and reverse osmosis are the only known processes that will effectively remove microbes, turbidity, sediment, colloidal matter, total dissolved solids, toxic metals, radioactive elements, pesticides and herbicides, when an appropriate pore size is used. Proper pre-treatment by de-gassing is required to remove volatile organics (VOCs). Seawater is a vast but largely untapped resource capable of supplying the world's water needs. Inland communities can use salty groundwater. The sun can provide energy for the process.

It is estimated there are currently 12,500 desalination plants throughout the world supplying 20 million m³ per day, or 1% of the world's production of drinking water (4.82 km³ per year). The world desalination market is expected to be worth more than \$US 70 billion in the next 20 years: \$10 billion has already been committed over the next 5 years (Martin-Lagardette, n.d). The desalination market for the Middle East, North Africa and Europe was valued at \$US 1.05 billion in 1999 and is predicted to reach \$2.54 billion in 2006 (Anon, 2000), while the Asian market is expected to grow at 11% per year till it hits \$US 1.3 billion in 2010 (EDIE, 2002).

5. PREDICTIONS

In a landmark work, Simonovic (2001) proposed four scenarios to his WorldWater computer model for the century from 2000 till 2100: business as usual (named "Chaos"), a moderate case named "Conservation 1", a more aggressive "Conservation 2", and unlimited desalination ("Ocean").

The Chaos scenario assumes that population growth is moderated and technologies develop to conserve resources, protect agricultural land, increase production and reduce pollution, but a conservative 700 km³ of wastewater is still disposed of in the environment (less than half 1995 levels). Despite these advances, the model predicts the death of approximately 5 billion people between 2040 and 2060 from lack of water. Simonovic writes that this scenario is highly unlikely as long as pressure is put on governments for policy change.

Conservation 1 assumes the same moderated population and industrial growth and new technologies, but with a doubling of current desalination capacity (10 km³ per year), an increase of water reuse from 20% to 50%, and an increase in water treatment levels so that dilution rates gradually decline from 9:1 to 5:1. In this case around 4 billion lives are lost from 2040 to 2050.

Conservation 2 improves on the previous scenario by aggressively improving wastewater treatment. Even this isn't enough as population shock still occurs around 2040 with 2 billion dying.

The Ocean scenario maintains the same assumptions as Chaos except that desalination is unlimited, and reaches a peak of 9,000 km³ by 2040 (1,867 times current capacity). World population reaches equilibrium at 8 billion by 2060 and maintains its standard of living without collapse, and without major economic impact. This scenario is unlikely however since water problems are regional and Simonovic does not expect the world to share finances to solve regional water problems. The Ocean case also assumes that desalination has no negative effect on the environment, however Sadiq (2002) showed that brine discharge areas were high in cadmium, cobalt, copper, mercury, vanadium, iron, phosphorous and zinc.

Simonovic concludes by saying that action is required now, a global crisis is already happening, and that, if not dealt with, water pollution will dramatically decrease the global population in the 21st century with people in less developed regions paying a very heavy price

6. CONCLUSIONS

The dire predictions of Simonovic and the World Water Model are based on the assumption that "world society proceeds along its historical path as long as possible without major policy change" (Simonovic, 2001). Social commentators surmise that human civilisations fail for four main reasons: failure to foresee a problem, failure to acknowledge a problem, failure to conceive solutions to a problem, and failure to solve the problem (SMH, 2003). It is always preferable to avoid end-of-pipe solutions where timely intervention at the source will eliminate the problem. Better management of existing freshwater and reuse of wastewater in a sustainable water cycle are acknowledged as the best and most cost effective solutions. However, should this continue to be left undone, then desalination with renewable energy may well represent the last best hope humanity has.

The authors' course of study is attempting to produce a system with the following important characteristics:

- High efficiency;
- Large capacity of one unit and/or a group of units;
- Self-sustainable performance for use at any place with only renewable energy
- A long life span to recover initial investment and energy consumption;
- Simple operation and maintenance;
- No special materials being required for the production and maintenance;
- Environmentally tough and friendly system.

A solar powered vacuum membrane distillation process using hollow fibres and vapour compression is the system of choice thus far. Reports of operation will be made in the future.

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